

What is Claimed:

1. An illumination system comprising:
 - 5 a light source for emitting light of selected wavelength(s) in an optical path toward a pupil.
 - means for shaping the light from the source into a shaped illumination pattern having one or more zones where the intensity of the light in the zones varies to produce a shaped illumination pattern for each zones;
 - 10 means for optically integrating light incident on the pupil;
 - a square shaped aperture disposed proximate the pupil for squaring the edges of the shaped illumination distribution pattern; and
 - optical means for combining the shaped illumination to illuminate a photomask.
- 15 2. The illumination system of claim 1 wherein the means for shaping the light comprises a plurality of masking apertures.
3. The illumination system of claim 2 wherein one of the masking apertures
 - 20 comprises an opaque plate with one or more apertures.
4. The illumination system of claim 3 wherein one of the masking apertures comprises a translucent plate with a central obscuration.
- 25 5. The illumination system of claim 4 wherein the obscuration is circular or square.
6. The illumination system of claim 1 wherein the means for optically integrating light is a fly's eye lens.
- 30 7. The illumination system of claim 1 wherein the square shaped aperture comprises a translucent substrate and a square pattern or a metal plate with a square aperture.

8. The illumination system of claim 1 wherein the shaped illumination pattern has a shape selected from the group consisting of round, square, and elliptical shapes.
9. The illumination system of claim 8 wherein the means for shaping the light
5 comprises one or more diffractive optical elements.
10. The illumination system of claim 8 wherein the means for shaping the light from the source comprises one or more beam splitters located between the source of light and the pupil.
- 10 11. The illumination system of claim 10 wherein the optical means for combining the shaped illumination pattern comprises a refractive element for each beam.
12. The illumination system of claim 1 wherein the means for shaping an
15 illumination pattern comprises a masking aperture comprising:
a translucent substrate;
a half-tone dithered image on the substrate, said half-tone dithered image comprising an array of pixels, each pixel of a clear or opaque type and of the same size, said clear and opaque pixels for respectively passing and blocking incident light,
20 wherein the number, size, and type of the pixels are chosen in accordance with:
(a) the wavelength of light used to illuminate the photomask, and
(b) the size and shape of the features of the photomask, for generating a continuous illumination intensity pattern on the photomask with illumination intensity at any location controlled by the half-tone dithered image.
- 25 13. The illumination system of claim 12 wherein the half-tone dithered image comprises an array of diffraction elements and each diffraction element is a dither image of clear or opaque pixels.
- 30 14. The illumination system of claim 12 wherein the square aperture is formed the same as the dithered image.
15. The illumination system of claim 13 wherein each diffraction element pixel comprises an $n \times n$ dithered matrix of pixels, the intensity of each element is defined

by the number and type of pixels in its dithered matrix and wherein the pixels in each matrix are dithered to avoid artifacts.

16. The illumination system of claim 13 wherein the relative intensity of each subpixel is defined by a recursion relationship where:

$$D^n = \begin{bmatrix} 4D^{n/2} + D_{00}^2 U^{n/2} & 4D^{n/2} + D_{01}^2 U^{n/2} \\ 4D^{n/2} + D_{10}^2 U^{n/2} & 4D^{n/2} + D_{11}^2 U^{n/2} \end{bmatrix}$$

where:

10

$$U^n = \begin{bmatrix} 1 & 1 & \dots & 1 \\ 1 & & & \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ 1 & & & \end{bmatrix}$$

17. The illumination system of claim 16 wherein the matrix of pixels comprises an 8 x 8 matrix and the relative intensity, D^8 , comprises:

15

$$D^8 = \begin{bmatrix} 0 & 32 & 8 & 40 & 2 & 34 & 10 & 42 \\ 48 & 16 & 56 & 24 & 50 & 18 & 58 & 26 \\ 12 & 44 & 4 & 36 & 14 & 46 & 6 & 38 \\ 60 & 28 & 52 & 20 & 62 & 30 & 54 & 22 \\ 3 & 35 & 11 & 43 & 1 & 33 & 9 & 41 \\ 51 & 19 & 59 & 27 & 49 & 17 & 57 & 25 \\ 15 & 47 & 7 & 39 & 13 & 45 & 5 & 37 \\ 63 & 31 & 55 & 23 & 61 & 29 & 53 & 21 \end{bmatrix}$$

18. The system of claim 1 wherein the means for optically integrating light on the pupil is a plurality of fly's eye lenses.

20

19. An illumination system comprising:

a light source for emitting light of selected wavelength(s) in an optical path toward a pupil.

means for shaping the light from the source into a shaped illumination pattern

- 25 having one or more zones where the intensity of the light in the zones varies to

produce a shaped illumination pattern for each zones and wherein the zone is shaped from the group consisting of ellipses, square rings, stepped square rings and combinations thereof:

- 5 means for optically integrating light incident on the pupil; and
optical means for combining the shaped illumination to illuminate a photomask.

20. The illumination system of claim 19 further comprising means for shaping the light into additional patterns selected from the group consisting of circles, squares,
10 rectangles and circular rings.

21. A method for controlling on-axis and off-axis illumination of a photomask comprising the steps of:
directing a beam of light of a selected wavelength toward a pupil of an
15 illumination system;
passing the beam of light through a fly's eye lens located near the pupil;
diffracting the light to form a pattern of illumination intensity in one or more zones wherein each zone has a shape corresponding to shapes selected from the group consisting of ellipses, square rings, stepped squares and combinations thereof.
20
22. The method of claim 21 further diffracting the light beam to form one or more additional patterns of light intensity selected from the group consisting of circles, squares, rectangles and circular rings.